

Uncertainties in the Retrieval of Optical Thickness and Droplet Radius for Liquid Water Clouds

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- Optical thickness (τ) and effective cloud droplet effective radius (r_{eff}) are the major cloud parameters for determining current, and future, cloud energetics/forcings; processes in cloud development; parameterizations for GCM's; ...
- Desired accuracy for both parameters depends on the application

$$\text{e.g., Cloud Albedo} \approx \frac{\tau}{13 + \tau}$$

$$\text{Liquid Water Path (g/cm}^2\text{)} \propto \tau r_{eff}$$

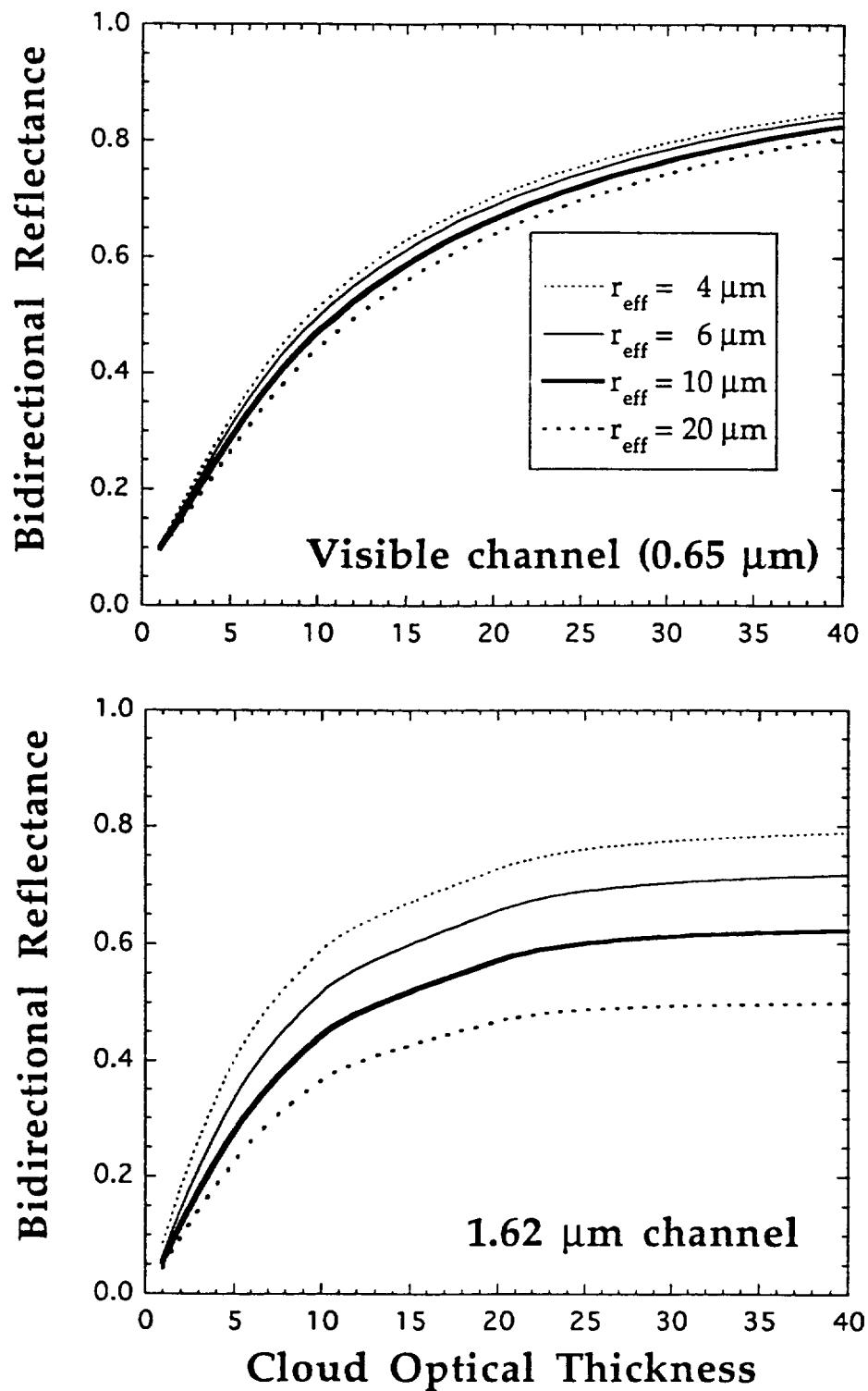
$$\begin{aligned} &\text{Cloud Susceptibility (sensitivity to CCN} \\ &\text{concentrations)} \propto \frac{\partial \text{Albedo}}{\partial \tau} \tau r_{eff}^3 \end{aligned}$$

- Solar reflectance at a non-absorbing (visible) wavelength provides information primarily regarding optical thickness:
 - 0.64 μm MODIS channel

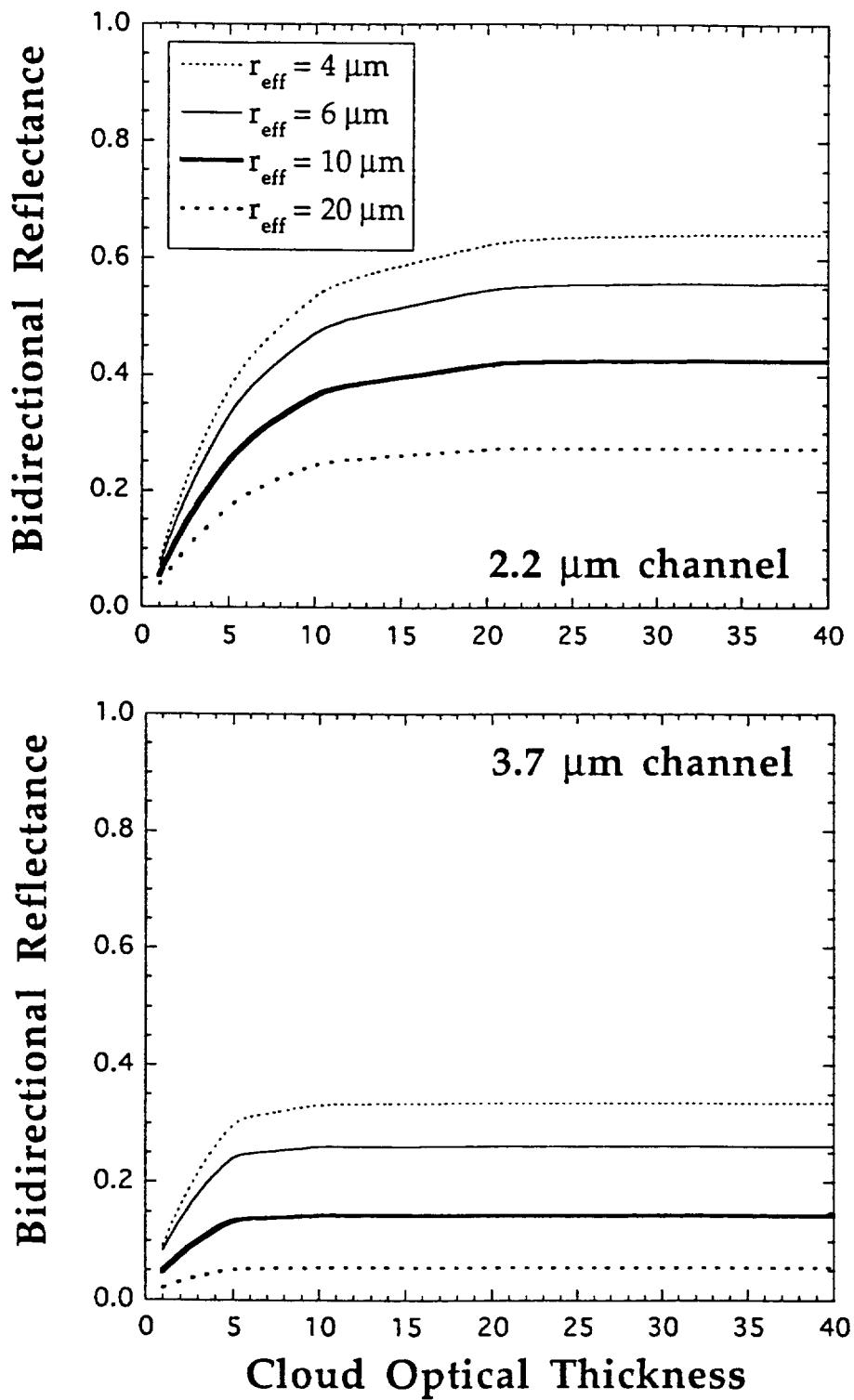
Reflectance at absorbing wavelengths provides information primarily regarding droplet size:

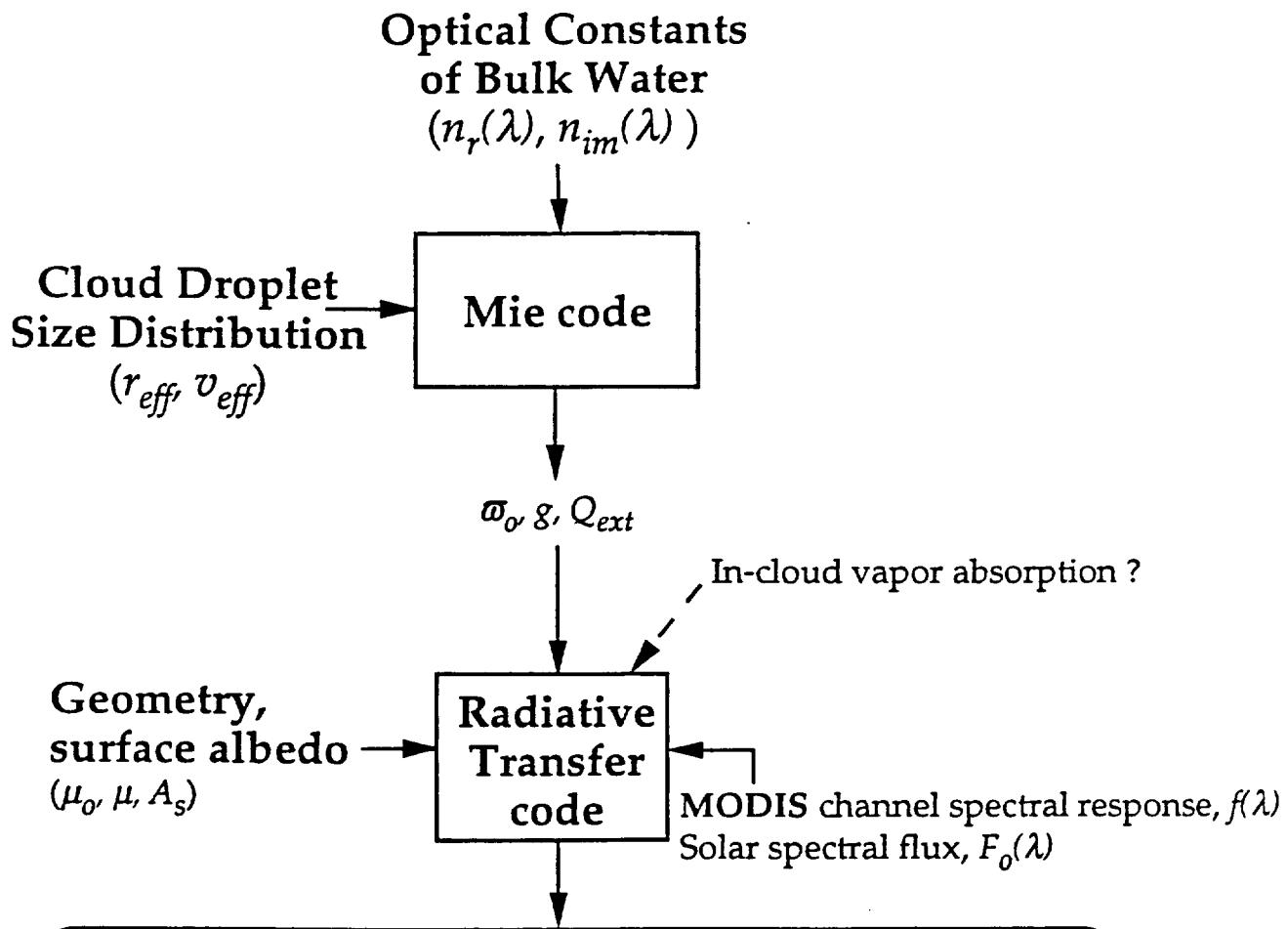
 - 1.6 μm , 2.2 μm , and 3.7/3.9 μm MODIS channels
- Uncertainties result largely from:
 - MODIS calibration, atmospheric corrections
 - Uncertainty in cloud reflectance calculations

$\mu_o = 0.75, \mu_{sat} = 0.95$
Optical Constants from Irvine & Pollack (1968)



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Bidirectional Reflectance:

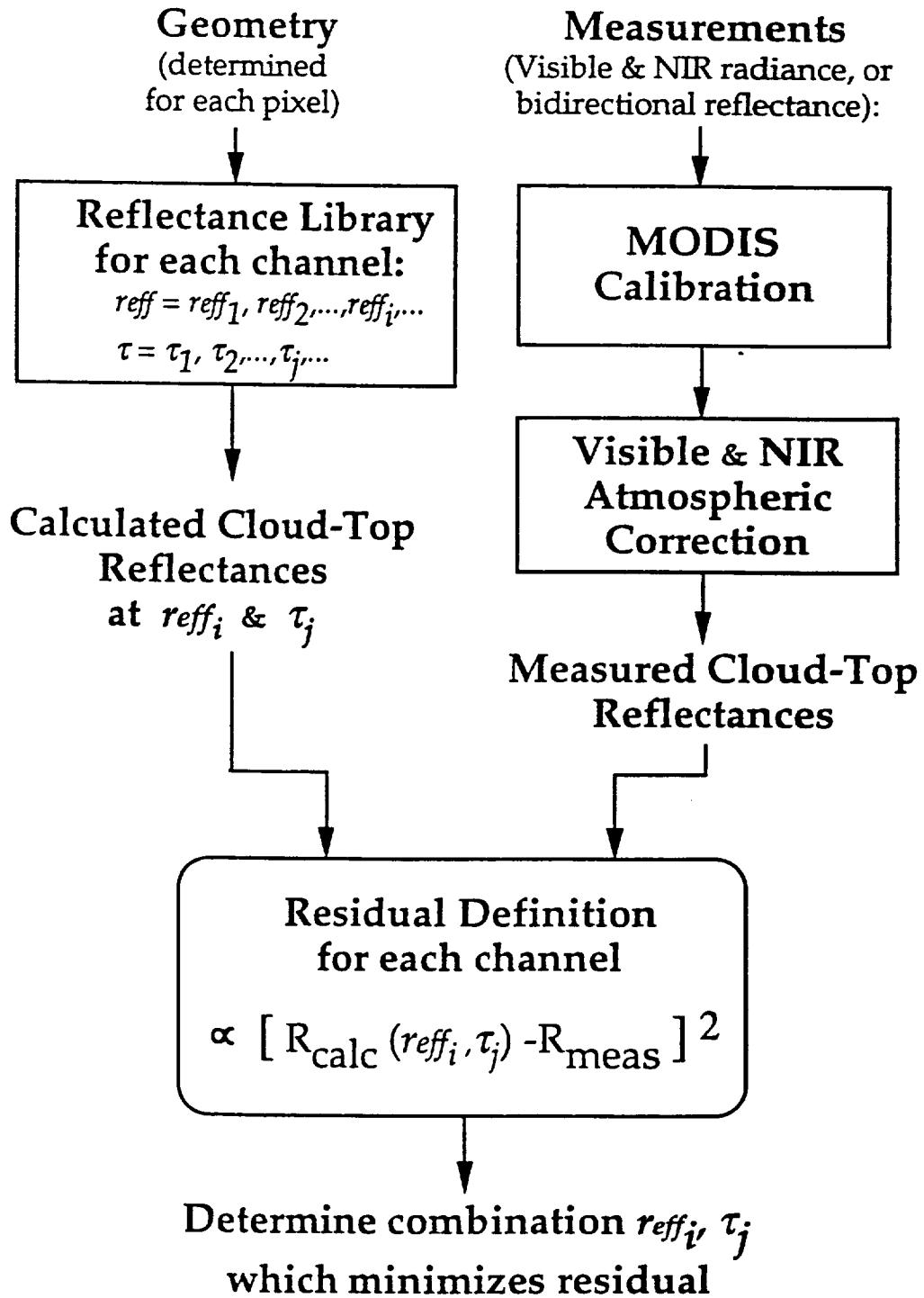
$$R = \frac{\int_{\lambda} R_{\lambda}(r_{eff}, \tau, \mu_o, \mu, \phi) f(\lambda) F_o(\lambda) d\lambda}{\int_{\lambda} f(\lambda) F_o(\lambda) d\lambda}$$

for each MODIS channel–
0.64, 1.6, 2.2, 3.7 μm

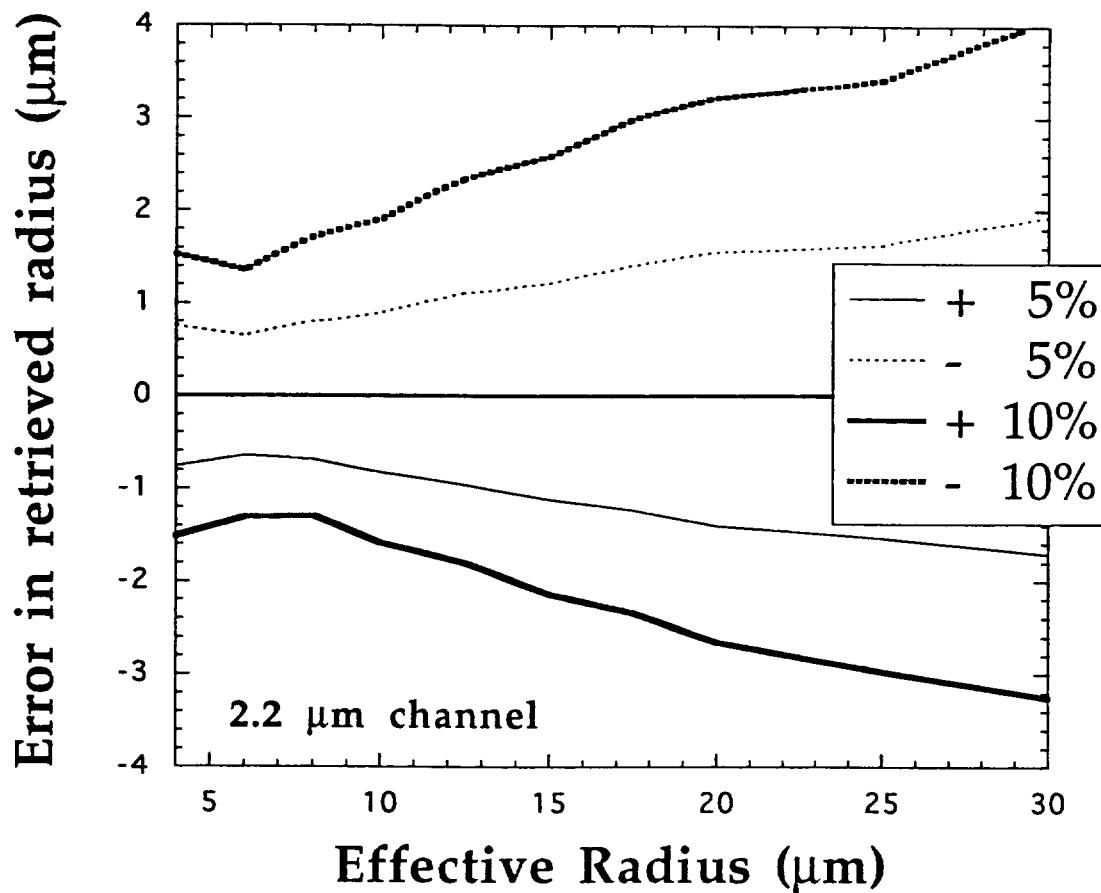
Effective Emissivity:

of cloud and surface for
MODIS 3.7 μm and
thermal IR channels

*(library calculations made for some combination:
r_{eff}=r_{eff1}, r_{eff2}, ...; τ=τ₁, τ₂, ...; μ_o=μ_{o1}, μ_{o2}, ...;
μ=μ₁, μ₂, ...; harmonics in φ)*



Retrieved error due to $\pm 5\%$ and $\pm 10\%$ reflectance error
 $\mu_{\text{sat}}=0.95, \mu_{\text{solar}}=0.75, \tau=50$



Summary of approximate minimum & maximum absolute uncertainty (μm) in retrieving effective radius for MODIS near infrared channels (for clouds with $r_{eff} = 4 \mu\text{m}$ to $20 \mu\text{m}$, $\mu=0.95$; μ_o variable and optically thick unless otherwise specified).

MODIS Channel	$\langle R \rangle \lambda$ vs. $R \langle \text{Mie} \rangle \lambda$	$\pm \lambda_c$ shift ($\pm 13\%$ of BW)	Sensor radiance or reflectance uncertainty ($\mu_o=0.75$) = $\pm 5\%$ $\pm 10\%$	Optical Constants (n_r , n_{im})	In-cloud Vapor Absorption ($\mu_o=0.75$, w/out continuum)	Size Distribution (& v_{eff} sensitivity)
1.64 μm	0.01 , 0.09	0.10 , 0.55	1.0 , 3.0 2.0 , 6.0	0.5 , 3.0	0.10 , 0.20	0.1 , 1.3
2.15 μm	0.05 , 0.30	0.15 , 0.50	0.7 , 1.5 1.4 , 3.2	0.6 , 2.6	0.10 , 0.60	0.1 , 1.2
3.73 μm	0.10 , 0.25	0.30 , 0.70	0.4 , 0.8 0.6 , 1.7		0.10 , 0.30	0.1 , 1.4

